JC14 Rec'd PCT/PTO 08 JAN 2002

FORM PTO-1390 REV. 2/01T U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE **TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371**		ATTORNEY'S DOCKET NUMBER 08364.0033 U S. APPLICATION NO. (If known, see 37CFR1.5) 10/030357
INTERNATIONAL APPLICATION NO. PCT/GB00/02633	INTERNATIONAL FILING DATE July 10, 2000	PRIORITY DATE CLAIMED July 8, 1999

TITLE OF INVENTION
SIGNALLING SYSTEM

APPLICANT(S) FOR DO/EO/US
Alan Edward GREEN and Euan MORRISON

Applicant(s) herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c)(2)).
   - a. ☒ is attached hereto (required only if not communicated by the International Bureau.
   - b. ☒ has been communicated by the International Bureau.
   - c. ☐ is not required, as the application was filed with the United States Receiving Office (RO/US).
6. ☐ An English language translation of the International Application as filed (35 U.S.C. 371 (c)(2)).
   - a. ☐ is attached hereto.
   - b. ☐ has been previously submitted under 35 U.S.C. 154 (d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3)).
   - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   - b. ☐ have been communicated by the International Bureau.
   - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   - d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371 (c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. ☐ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

Items 11 to 20 below concern document(s) or information included:

11. ☒ Information Disclosure Statement under 37 CFR 1.97 and 1.98
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A FIRST preliminary amendment.
14. ☐ A SECOND or SUBSEQUENT preliminary amendment.
15. ☐ A Substitute specification.
16. ☐ A change of power of attorney and/or address letter.
17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821-1.825.
18. ☐ A second copy of the published international application under 35 U.S.C. 154 (d)(4).
19. ☐ A second copy of the English language translation of the international application 35 U.S.C. 154 (d)(4).
20. ☒ Other items or information:
   - a. ☒ Copy of cover page of International Publication No. WO 01/05072
   - b. ☐ Copy of Notification of Missing Requirements.
   - c. ☐

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U.S. APPLICATION NO. (If known, see 37 CFR 1.5) 10/030357	INTERNATIONAL APPLICATION NO. PCT/GB00/02633	ATTORNEY'S DOCKET NUMBER 08364.0033

21. ☒ The following fees are submitted:

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)):

CALCULATIONS PTO USE ONLY

Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO **$1040.00**

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO **$890.00**

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search fee (37 CFR 1.445(a)(2)) paid to USPTO **$740.00**

International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) **$710.00**

International preliminary examination fee (37 CFR 1.482) paid to USPTOand all claims satisfied provisions of PCT Article 33 (1)-(4) **$100.00**

ENTER APPROPRIATE BASIC FEE AMOUNT =					$890.00	
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).					$	
CLAIMS	NUMBER FILED		NUMBER EXTRA	RATE		
Total Claims	68	- 20 =	48	x $18.00	$864.00	
Independent Claims	5	-3 =	2	x $84.00	$168.00	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)				+$280.00	$	
TOTAL OF THE ABOVE CALCULATIONS =					$1922.00	
☐ Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by ½.					$	
SUBTOTAL =					$1922.00	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest priority date (37 CFR 1.492(f)).					$	
TOTAL NATIONAL FEE =					1922.00	
Fee for recording the enclosed assignment (37 CFR 1.21 (h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property. +					$	
TOTAL FEES ENCLOSED =					$1922.00	
					Amount to be refunded:	$
					charged:	$

a. ☒ A check in the amount of $ 1922.00 to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. ________ in the amount of $ ________ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 06-0916. A duplicate copy of this sheet is enclosed.

d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137 (a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Finnegan, Henderson, Farabow, Garrett & Dunner, L.L.P.
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SIGNATURE

Ernest F. Chapman/25,961

NAME/REGISTRATION NO.

DATED: January 8, 2002

10/030357

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PATENT
Attorney Docket No. 08364.0033
CUSTOMER NUMBER 22,852

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	Group Art Unit: Not assigned
Inventor: Alan Edward GREEN et al.	Examiner: Not assigned
Serial No.: Not Yet Assigned	
Filed: January 8, 2002	
U.S. National Phase Application No. PCT/GB00/02633	
For: SIGNALLING SYSTEM	

BOX PCT

Assistant Commissioner for Patents
Washington, DC 20231

Sir:

PRELIMINARY AMENDMENT

Prior to examination, please amend the above-identified application as follows:

IN THE SPECIFICATION:

Please amend the specification as follows:

Page 1, after the title insert a new paragraph as follows:

--CROSS REFERENCE TO RELATED APPLICATIONS

This application is national phase application based on International Application Number PCT/GB00/02633, filed on July 10, 2000, and claims

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the priority of Great Britain Patent Application No. 9916081.4, filed July 8, 1999 and Great Britain Patent Application No. 9916082.2, filed July 8, 1999.--

IN THE CLAIMS:

Please cancel claims 1 - 46 without prejudice or disclaimer and substitute pending claims 47 - 114 therefor as follows:

47. (New) An optical signalling system comprising first and second signalling devices,

the first signalling device comprising a first receiver operable to receive an optical signal transmitted from said second signalling device; and a modulator operable to modulate the received optical signal with modulation data for the second signalling device and to reflect the received signal back to the second signalling device; and

the second signalling device comprising: a second receiver operable to receive the reflected optical signal from said first signalling device carrying said modulation data; a data retriever operable to retrieve the modulation data from said reflected signal; a signal generator operable to generate an optical signal; a steerer operable to controllably steer the optical signal generated by said signal generator towards said first signalling device; a sensor operable to sense the signal strength of the reflected optical signal; and a controller operable to control said steerer in dependence upon the sensed signal strength.

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48. (New) A system according to claim 47, wherein said steerer comprises a reflector operable to reflect said optical signal.

49. (New) A system according to claim 48, wherein said steerer comprises one or more mirrors pivotally mounted relative to said generated optical signal.

50. (New) A system according to claim 47, wherein said steerer comprises a diffractive element operable to diffract said generated optical signal.

51. (New) A system according to claim 50, wherein said diffractive element comprises a moving diffraction grating.

52. (New) A system according to claim 50, wherein said diffractive element comprises a hologram.

53. (New) A system according to claim 52, wherein said hologram is movable relative to the generated optical signal.

54. (New) A system according to claim 47, wherein said steerer comprises a refractive element operable to refract the generated optical signal.

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55. (New) A system according to claim 54, wherein said refractive element comprises first and second prisms.

56. (New) A system according to claim 55, wherein said steerer is operable to steer said generated optical signal by rotating said prisms relative to said generated optical signal.

57. (New) A system according to claim 56, wherein said first and second prisms are rotatable about the axis of the generated optical signal and wherein said steerer is operable to rotate the two prisms in opposite directions to steer the generated optical signal in a first direction and is operable to rotate the first and second prisms in the same direction to steer the generated optical signal in a second direction different to the first direction.

58. (New) A system according to claim 55, wherein said first and second prisms are wedge shaped.

59. (New) A system according to claim 47, wherein said sensor is operable to monitor the signal strength of said reflected optical signal and wherein said controller is operable to control said steerer in dependence upon the monitored signal levels.

60. (New) A system according to claim 47, wherein said controller is operable to oscillate said steerer, wherein said sensor is operable to sense a variation in the signal strength caused by said oscillation and wherein

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said controller is operable to control said steerer in dependence upon the sensed variation.

61. (New) A system according to claim 60, wherein said sensor comprises a phase sensitive amplitude modulation detector.

62. (New) A system according to claim 61, wherein said controller is operable to oscillate said steerer in accordance with at least one dither signal and wherein said detector comprises a mixer operable to mix said reflected signal with the at least one dither signal.

63. (New) A system according to claim 47, wherein said controller comprises a microprocessor.

64. (New) A system according to claim 47, wherein said signal generator is operable to generate an optical signal at a first power level and wherein said second signalling device further comprises a power controller operable to reduce the power output of said signal generator to a second power level in dependence upon the signal level of said reflected signal sensed by said sensor.

65. (New) A system according to claim 64, wherein said sensor is operable to monitor a recent history of the received signal level and wherein said power controller is operable to reduce the power output of said signal generator in dependence upon said recent history.

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66. (New) A system according to claim 65, wherein said sensor is operable to sense the level of the reflected signal at regular intervals and wherein said power controller is operable to reduce the power output of said signal generator if the change in signal level between sensing intervals exceeds a predetermined threshold.

67. (New) A system according to claim 47, wherein said controller comprises one or more stepper motors for controlling said steerer.

68. (New) A system according to claim 47, wherein said first signalling device further comprises a focussing device operable to focus the received optical signal onto said reflector.

69. (New) A system according to claim 68, wherein said focussing device comprises a telecentric lens and wherein said reflector is located substantially at the focal plane of said telecentric lens.

70. (New) A system according to claim 69, wherein said telecentric lens is a wide angled telecentric lens.

71. (New) A system according to claim 68, wherein said modulator is transmissive and is located between said focussing device and said reflector.

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72. (New) A system according to claim 47, wherein said modulator and said reflector are co-located.

73. (New) A system according to claim 47, wherein said modulator and said reflector are separate elements.

74. (New) A system according to claim 47, wherein said first signalling device comprises a plurality of modulators operable to modulate and reflect optical signals received from a plurality of second signalling devices.

75. (New) A system according to claim 74, wherein said plurality of modulators are arranged in an array.

76. (New) A system according to claim 75, wherein said plurality of modulators are arranged in a regular array.

77. (New) A system according to claim 75, wherein said plurality of modulators are arranged in a two dimensional array.

78. (New) A system according to claim 47, wherein said reflector comprises a retro-reflector.

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79. (New) A system according to claim 47, wherein said modulator is operable to modulate at least one of the amplitude, phase, frequency and polarisation of the received signal.

80. (New) A system according to claim 47, wherein said modulator comprises a quantum confined stark effect device.

81. (New) A system according to claim 47, wherein said second signalling device is operable to transmit a message to said first signalling device and wherein said first signalling device comprises an information retriever operable to retrieve the message from the received signal.

82. (New) A system according to claim 47, wherein said signal generator comprises at least one of a laser, a laser diode and a light emitting diode.

83. (New) A system according to claim 47, wherein said second signalling device further comprises an optical beam expander for increasing the diameter of the optical signal output towards said first signalling device.

84. (New) A signalling device comprising:

a signal generator operable to generate an optical signal;

a receiver operable to receive an optical signal carrying modulation data from a remote signalling device;

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a data retriever operable to retrieve the modulation data from said reflected signal;

a steerer operable to controllably steer the optical signal generated by said signal generator towards said remote signalling device;

a sensor operable to sense the signal strength of the received optical signal; and

a controller operable to control said steering means in dependence upon the sensed signal strength.

85. (New) A signalling device according to claim 84, wherein said steerer comprises a reflector operable to reflect said optical signal.

86. (New) A signalling device according to claim 85, wherein said steerer comprises one or more mirrors pivotally mounted relative to said generated optical signal.

87. (New) A signalling device according to claim 84, wherein said steerer comprises a diffractive element operable to diffract said generated optical signal.

88. (New) A signalling device according to claim 87, wherein said diffractive element comprises a moving diffraction grating.

89. (New) A signalling device according to claim 88, wherein said diffractive element comprises a hologram.

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90. (New) A signally device according to claim 89, wherein said hologram is movable relative to the generated optical signal.

91. (New) A signalling device according to claim 84, wherein said steerer comprises a refractive element operable to refract the generated optical signal.

92. (New) A signally device according to claim 91, wherein said refractive element comprises a first and second prism.

93. (New) A signalling device according to claim 92, wherein said steerer is operable to steer said generated optical signal by rotating said prisms relative to said generated optical signal.

94. (New) A signalling device according to claim 93, wherein said first and second prisms are rotatable about the axis of the generated optical signal and wherein said steerer is operable to rotate the two prisms in opposite directions to steer the generated optical signal in a first direction and is operable to rotate the first and second prisms in the same direction to steer the generated optical signal in a second direction different to the first direction.

95. (New) A signalling device according to claim 92, wherein said first and second prisms are wedge shaped.

96. (New) A signalling device according to claim 84, wherein said sensor is operable to monitor the signal strength of said reflected optical signal and wherein said controller is operable to control said steerer in dependence upon the monitored signal levels.

97. (New) A signalling device according to claim 84, wherein said controller is operable to oscillate said steerer, wherein said sensor is operable to sense a variation in the signal strength caused by said oscillation and wherein said controller is operable to control said steerer in dependence upon the sensed variation.

98. (New) A signalling device according to claim 97, wherein said sensor comprises a phase sensitive amplitude modulation detector.

99. (New) A signalling device according to claim 98, wherein said controller is operable to oscillate said steerer in accordance with at least one dither signal and wherein said detector comprises a mixer operable to mix said reflected signal with the at least one dither signal.

100. (New) A signalling device according to claim 84, wherein said controller comprises a microprocessor.

101. (New) A signalling device according to claim 84 wherein said signal generator is operable to generate an optical signal at a first power level, and wherein said signalling device further comprises a power controller

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operable to reduce the power output of said signal generator to a second power level in dependence upon the signal level of said reflected signal sensed by said sensor.

102. (New) A signalling device according to claim 101, wherein said sensor is operable to monitor a recent history of the received signal level and wherein said power controller is operable to reduce the power output of said signal generator in dependence upon said recent history.

103. (New) A signalling device according to claim 102, wherein said sensor is operable to sense the level of the reflected signal at regular intervals and wherein said power controller is operable to reduce the power output of said signal generator if the change in signal level between sensing intervals exceeds a predetermined threshold.

104. (New) A signalling device according to claim 84, wherein said controller comprises at least one stepper motor for controlling said steerer.

105. (New) A signalling device according to claim 84, wherein said signal generator comprises at least one of a laser, a laser diode and a light emitting diode.

106. (New) A signalling device according to claim 84, further comprising an optical beam expander for increasing the diameter of the optical signal output towards the remote signalling device.

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107. (New) A signalling kit comprising one or more first signalling devices and one or more second signalling devices, wherein each of said second signalling devices comprises a signalling device according to claim 84.

108. (New) An optical signalling method using first and second signalling devices, the method comprising:

at the first signalling device: receiving an optical signal transmitted from said second signalling device; modulating the received optical signal with modulation data for the second signalling device; and reflecting the received signal back to the second signalling device; and

at the second signalling device: generating an optical signal; outputting the optical signal towards said first signalling device; receiving the reflected optical signal from said first signalling device carrying said modulation data; and retrieving the modulation data from said reflected signal;

wherein at the second signalling device the outputting of the generated optical signal comprises:

controllably steering the generated optical signal towards said first signalling device;

sensing the signal strength of the reflected signal; and

controlling said steering step in dependence upon the sensed signal strength.

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109. (New) A retro-reflecting optical communications system comprising an optical source end and a reflecting end, wherein the source end comprises:

a steerer operable to controllably steer a generated optical signal towards said reflecting end;

a sensor operable to sense the signal strength of a reflected signal received back from said reflecting end; and

a controller operable to control said steerer in dependence upon the sensed signal strength.

110. (New) An optical signalling system comprising first and second signalling devices,

the first signalling device comprising: a first receiver operable to receive an optical signal transmitted from said second signalling device; a modulator operable to modulate the received optical signal with modulation data for the second signalling device; and a reflector operable to reflect the received signal back to the second signalling device; and

the second signalling device comprising: a second receiver operable to receive the reflected optical signal from said first signalling device carrying said modulation data; a data retriever operable to retrieve the modulation data from said reflected signal; a signal generator operable to generate an optical signal at a first power level; a sensor operable to sense the signal strength of the reflected signal; and a power controller operable to reduce the power output of said signal generator to a second

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power level lower than the first power level in dependence upon the sensed signal strength.

111. (New) A system according to claim 110, wherein said sensor is operable to monitor a recent history of the received signal level and wherein said power controller is operable to reduce the power output of said signal generator in dependence upon said recent history.

112. (New) A system according to claim 111, wherein said sensor is operable to sense the level of the reflected signal at regular intervals and wherein said power controller is operable to reduce the power output of said signal generator if the change in signal level between sensing intervals exceeds a predetermined threshold.

113. (New) A data distribution system comprising at least one signalling system according to claim 47.

114. (New) A data distribution system comprising at least one signalling system according to claim 110.

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REMARKS

The claims have been amended to eliminate multiple claim dependency and to conform them to U.S. practice. No new matter has been introduced by these amendments.

The examiner is respectfully requested to consider the above preliminary amendment prior to examination of the application.

If there are any fees due in connection with the filing of this amendment, please charge the fees to Deposit Account No. 06-0916. If a fee is required for an extension of time under 37 C.F.R. § 1.136 not accounted for above, such an extension is requested and the fee should also be charged to our deposit account.

Respectfully submitted,

FINNEGAN, HENDERSON, FARABOW, GARRETT & DUNNER, L.L.P.

Dated: January 8, 2002

By: ______________________
Ernest F. Chapman
Reg. No. 25,961

EFC/FPD/dvz

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SIGNALLING SYSTEM

The present invention relates to a signalling system. The invention has particular, although not exclusive, relevance to the alignment of an optical beam used in an optical communication system.

The applicant has proposed in their earlier International application WO 98/35328 a point to multipoint data transmission system which uses a retro-reflector to receive collimated laser beams from a plurality of user terminals, to modulate the received laser beams and to reflect them back to the respective user terminals. This point to multipoint data transmission system employs pixelated reflector/modulator arrays and a telecentric optical lens system. Each pixel in the array maps to a unique angular position in the field of view of the telecentric optical lens system. Communications with each of the user terminals is then achieved using the appropriate pixel in the array which maps to the direction in which the user terminal is located within the field of view.

In conventional free-space optical communication systems, a relatively divergent laser beam is used in order to ease alignment during installation and to allow the ends of the link to move over time and still maintain the link. However, the system described in the applicants earlier International application described above has the

disadvantage that the collection aperture at the modulator end is limited (by the telecentric lens) and the light undergoes twice the atmospheric loss due the retro-reflective nature of the system. It is possible to overcome the limitation of the telecentric aperture size by transmitting a beam with significantly lower divergence (down to the diffraction limit) over the ranges considered (approximately 200m). However, the use of such a narrow beam results in the problem that the user terminals must be accurately aligned with the retro-reflector and the problem that the system is sensitive to vibration or creepage of either end of the communication link.

The present invention aims to provide an alternative technique for maintaining alignment between the laser beam transmitted by the receiving end of the system towards the retro-reflector.

Exemplary embodiments of the present invention will now be described with reference to the accompanying drawings in which:

Figure 1 is a schematic diagram of a video broadcast system for supplying video signals for a plurality of television channels, to a plurality of remote users;

Figure 2 is a schematic block diagram of a local distribution node and a user terminal which forms part of

the video broadcast system shown in Figure 1;

Figure 3 is a schematic diagram of a retro-reflector array and lens system employed in the local distribution node shown in Figure 2;

Figure 4 is a schematic diagram of a pixelated modulator array forming part of the retro-reflecting modulator unit shown in Figure 3;

Figure 5 is a perspective schematic view of the components in the user terminal which forms part of the system shown in Figure 3;

Figure 6 is a plot illustrating the intensity profile of the laser beam generated by the user terminal shown in Figure 5;

Figure 7 is a block diagram illustrating a control circuit which forms part of the user terminal shown in Figure 5; and

Figure 8 is a perspective schematic view of an alternative user terminal which may be used in the system shown in Figure 3.

Figure 1 schematically illustrates a video broadcast system for supplying video signals, for a plurality of television channels, to a plurality of remote users. As

shown in Figure 1, the system comprises a central distribution system 1 which transmits optical video signals to a plurality of local distribution nodes 3 via a bundle of optical fibres 5. The local distribution nodes 3 are arranged to receive the optical video signals transmitted from the central distribution system 1 and to transmit relevant parts of the video signals to respective user terminals 7 (which are spatially fixed relative to the local distribution node 3) as optical signals through free space, i.e. not as optical signals along an optical fibre path.

In this embodiment, the video data for all the available television channels is transmitted from the central distribution system 1 to each of the local distribution nodes 3, each user terminal 7 informs the appropriate local distribution node 3 which channel or channels it wishes to receive (by transmitting an appropriate request) and, in response, the local distribution node 3 transmits the appropriate video data, to the respective user terminals 7. Each local distribution node 3 does not, however, broadcast the video data to the respective user terminals 7. Instead, each local distribution node 3 is arranged (i) to receive an optical beam transmitted from each of the user terminals 7 which are in its locality, (ii) to modulate the received beams with the appropriate video data for the desired channel or channels, and (iii) to reflect the modulated beams back to the respective user terminals 7. In addition to being

able to receive optical signals from the central distribution system 1 and from the user terminal 7, each of the local distribution nodes 3 can also transmit optical data, such as status reports, back to the central distribution system 1 via the respective optical fibre bundle 5, so that the central distribution system 1 can monitor the status of the distribution network.

Figure 2 schematically illustrates in more detail the main components of one of the local distribution nodes 3 and one of the user terminals 7 of the system shown in Figure 1. As shown in Figure 2, the local distribution node 3 comprises a communications control unit 11 which (i) receives the optical signals transmitted along the optical fibre bundle 5 from the central distribution system 1; (ii) regenerates the video data from the received optical signals; (iii) receives messages 12 transmitted from the user terminals 7 and takes appropriate action in response thereto; and (iv) converts the appropriate video data into data 14 for modulating the respective light beams 15 received from the user terminals 7. In converting the video data into modulation data 14, the communications control unit 11 will encode the video data with error correction coding and coding to reduce the effects of inter-symbol-interference and other kinds of well known sources of interference such as from the sun and other light sources.

The local distribution node 3 also comprises a retro-reflector and modem unit 13, which is arranged to receive the optical beams 15 from the user terminals 7 which are within its field of view, to modulate the respective light beams with the appropriate modulation data 14 and to reflect the modulated beams back to the respective user terminals 7. In the event that an optical beam 15 received from one of the user terminals 7 carries a message 12, then the retro-reflector and modem unit 13 retrieves the message 12 and sends it to the communications control unit 11 where it is processed and the appropriate action is taken. In this embodiment, the retro-reflector and modem unit 13 has a horizontal field of view which is greater than +/- 50° and a vertical field of view of approximately +/- 5°.

Figure 2 also shows the main components of one of the user terminals 7. As shown, the user terminal 7 comprises a laser diode 17 for outputting a laser beam 19 of coherent light. In this embodiment, the user terminals 7 are designed so that they can communicate with the local distribution node 3 within a range of approximately 200 metres with a link availability of 99.9 per cent. To achieve this, the laser diode 17 is a 150 mW laser diode which outputs a laser beam having a wavelength of 850 nm. Although this is well above the operating limit which is classified as eye safe, this embodiment makes use of the fact that if the laser beam is interrupted by a person, then this will be detectable

at the receiver (since such an interruption of the beam causes an almost instantaneous drop in received signal level) and hence in this situation, the power output of the laser can be reduced to safe levels. As shown in Figure 2, the output laser beam 19 is passed through a collimator 21 which reduces the angle of divergence of the laser beam 19. The resulting laser beam 23 is passed through a beamsplitter 25 to a pair of steerable mirrors 26 which are used to steer the laser beam. The laser beam then passes through an optical beam expander 27, which increases the diameter of the laser beam to approximately 50 mm for transmittal to the retro-reflector and modem unit 13 located in the local distribution node 3. The optical beam expander 27 is used because a large diameter laser beam has a smaller divergence than a small diameter laser beam.

Using the optical beam expander 27 has the further advantage that it provides a fairly large collecting aperture for the reflected laser beam and it concentrates the reflected laser beam into a smaller diameter beam. The smaller diameter reflected beam is then split from the path of the originally transmitted laser beam by the beamsplitter 25 and focussed onto a photo-diode 29 by a lens 31. Since the operating wavelength of the laser diode 17 is 850nm, a silicon avalanche photo-diode (APD) can be used, which is generally more sensitive than other commercially available photo detectors, because of the low noise multiplication which can be achieved with these

devices. The electrical signals output by the photo-diode 29, which will vary in dependence upon the modulation data 14, are then amplified by the amplifier 33 and filtered by the filter 35. The filtered signals are then supplied to a control unit 37 which regenerates the clock and the video data using standard data processing techniques. The retrieved video data 38 is then passed to the user unit 39, which, in this embodiment, comprises a television receiver in which the video data is displayed to the user on a CRT (not shown).

The control unit 37 is also used to control the steering of the steerable mirrors 26 so that the laser beam is optimally aligned with the local distribution node 3. The control unit 37 also monitors and keeps a history of the recent signal strength so that, if the beam is interrupted, it can pass a control signal to the laser control unit 41 so that the power of the laser diode 17 is reduced to a class 1 level (0.25mW). Provided this power reduction can be achieved within one millisecond of the beam being interrupted, this would provide a system which could be considered as class 1 eye safe. As those skilled in the art will appreciate, by monitoring the recent history of the received signal strength, the control unit 37 can distinguish between slowly varying signal levels (caused for example by deteriorating atmospheric conditions) and sudden interruptions caused by, for example, a person interrupting the beam.

In this embodiment, the user unit 39 can receive an input from the user, for example indicating the selection of a desired television channel, via a remote control unit (not shown). In response, the user unit 39 generates an appropriate message 12 for transmittal to the local distribution node 3. This message 12 is output to the laser control unit 41 which controls the laser diode 17 so as to cause the laser beam 19 output from the laser diode 17 to be modulated with the message 12. As those skilled in art will appreciate, in order that the data being transmitted in opposite directions do not interfere with each other, different modulation techniques should be employed. For example, if the amplitude of the laser beam 15 is modulated by the local distribution node 3, then the laser control unit 41 should modulate, for example, the phase of the transmitted laser beam. Alternatively, the laser control unit 41 could apply a small signal modulation to the laser beam 19 to create a low-bandwidth control channel between the user terminal 7 and the local distribution node 3. This is possible provided the detector in the local distribution node 3 can detect the small variation in the amplitude of the received laser beam. Furthermore, such a small signal amplitude modulation of the laser beam would not affect a binary "on" and "off" type modulation which could be employed by the retro-reflector and modem unit 13.

The structure and function of most of the components in the user terminal 7 are well known to those skilled in

the art and a more detailed description of them shall, therefore, be omitted. However, a more detailed description of the steerable mirrors 26 and the control unit 37 will be given later.

Figure 3 schematically illustrates the retro-reflector and modem unit 13 which forms part of the local distribution node 3 shown in Figure 2. As shown, in this embodiment, the retro-reflector and modem unit 13 comprises a wide angle telecentric lens system 51 and an array of modulators and detectors 53. The design of such a wide angle telecentric lens using fisheye lens techniques is well known to those skilled in the art. In this embodiment, the telecentric lens 51 comprises lens elements 61 and 55 and a stop member 57, having a central aperture 59. The size of the aperture 59 is a design choice and depends upon the particular requirements of the installation. The structure and function of the telecentric lens system is described in the applicants earlier International application WO 98/35328, the contents of which are incorporated herein by reference.

As illustrated in Figure 3 by the two sets of rays 67 and 69, laser beams from different sources are focussed onto different parts of the array of modulators and detectors 53. Therefore, by using an array of separate modulators and detectors, the laser beams 15 from all the user terminals 7 can be separately detected and modulated by

a respective modulator and detector pair. Figure 4 is a schematic representation of the front surface (i.e. the surface facing the lens system 51) of the modulator and detector array 53 which, in this embodiment, comprises 100 columns of modulator/detector cells and 10 rows of modulator/detector cells (not all of which are shown in the figure). Each modulator/detector cell c_{ij} comprises a modulator m_{ij} and a detector d_{ij} located adjacent the corresponding modulator. In this embodiment, the size 71 of the cells c_{ij} is between 50 and 200 μm, with the spacing (centre to centre) 72 between the cells being slightly greater than the cell size 71.

The telecentric lens 51 is designed so that the spot size of a focussed laser beam from one of the user terminals 7 corresponds with the size 71 of one of the modulator/detector cells c_{ij}, as illustrated by the shaded circle 73 shown in Figure 4, which covers the modulator/detector cell c_{22}.

In this embodiment, Quantum Confined Stark Effect (QCSE, sometimes also referred to as Self Electro-optic Effect Devices or SEEDs) modulators, developed by the American Telephone and Telegraph Company (AT&T), are used for the modulators m_{ij}. The structure and function of these QCSE modulators is described in WO 98/35328 and will not be given here. In this embodiment, each of the detectors d_{ij} comprises a photo-diode which is connected to an associated amplifier, filter and clock recovery and data

retrieval unit, which operate to detect any modulation of the corresponding laser beam and to regenerate any messages 12 which are transmitted from the corresponding user terminal 7. All the recovered messages 12 are then transmitted back to the communications control unit 11 where they are processed and appropriate actions are taken.

The way in which the laser beam is steered by the steerable mirrors 26 will now be described with reference to Figures 5 to 7. Figure 5 is a perspective schematic view of the user terminal shown in Figure 2. As shown, light from the laser diode 17 passes through a collimator lens 21 and through a beamsplitter 25 to the steerable mirrors 26-1 and 26-2. As shown, steerable mirror 26-1 is mounted for rotation on the drive shaft 81-1 of motor 83-1 and can therefore be rotated about the vertical axis 85 of the shaft 81-1. The mirror 26-1 can therefore be used to steer the laser beam horizontally. As shown in Figure 5, the laser beam reflected from the mirror 26-1 hits the mirror 26-2 which is mounted for rotation with the drive shaft 81-2 of the second motor 83-2. As shown, the drive shaft 81-2 is operable to rotate the mirror 26-2 about the horizontal axis 87. As a result, the mirror 26-2 can steer the laser beam in the vertical direction. Consequently, the combination of the two mirrors 26-1 and 26-2 can steer the laser beam in any desired direction towards the appropriate local distribution load 3. In this embodiment, the control

unit 37 controls the positions of the mirrors 26-1 and 26-2 by outputting appropriate control signals to the motors 33-1 and 33-2. In particular the control unit 37 controls the motors 83 in order to maximise the level of the signal reflected from the local distribution node 3. As those skilled in the art will appreciate, typically the laser beam generated by the laser diode 17 will be non-uniform, and in many instances will approximately have a Gaussian profile. This is illustrated in Figure 6. Therefore, there will be a number of beam positions which give the same reflected signal strength. In order that the control unit 37 can detect this and determine the correct direction in which to steer the beam for maximum strength, it uses a phase sensitive detection technique. This is achieved by applying a small amplitude oscillation to each of the two mirrors 26-1 and 26-2. The resulting small modulation in the received signal strength (due to the oscillation of the mirrors) is detected by mixing the received signal with the modulating signal applied to the motors 83-1 and 83-2 used to cause the mirrors to oscillate. This is illustrated in Figure 7.

In particular, Figure 7 shows a dither signal generator 91 which generates the modulating signals used to cause the two mirrors 26 to oscillate. In this embodiment, dither signal generator 91 generates two dither signals 93-1 and 93-2 which are passed to a motor controller 95. The motor controller 95 uses the dither signal 93-1 to

control the motor 83-1 and it uses the dither signal 93-2 to control the motor 83-2. The signal 97 output from the filter 35 (shown in Figure 2) is input to two mixers 99-1 and 99-2 where the signal is mixed with a respective one of the two dither signals 93-1 and 93-2. As those skilled in the art will appreciate, the two dither signals 93-1 and 93-2 are preferably at different frequencies which are not harmonically related, in order that there is no cross talk between the signals derived from the respective mixers 99-1 and 99-2. The outputs from the mixers 99 are then filtered by a respective low pass filter 101-1 and 101-2 to remove the high frequency components. The filtered signals are then converted into digital signals by the analogue to digital converter 103 and then passed to the microprocessor 105 for processing.

When the laser beam is accurately aligned with the retro-reflector, the system will be operating near the peak of the curve shown in Figure 6. Therefore, in this case, the small oscillations will have little effect and small amplitude signals will be received by the microprocessor 105. If, however, the laser beam is misaligned and is operating off the peak shown in Figure 6, then larger signal levels will be output from one or both of the low pass filters 101. The sign of the signal will depend upon whether the mis-alignment is to the left or to the right of the peak. Therefore, the microprocessor 105 can process the signals output by the analogue to digital

converter 103 and output an appropriate control signal to the motor controller 95 to cause the mirrors 26 to be adjusted so that the beam is optimally aligned with the retro-reflector.

Figure 7 also shows that the control unit 37 includes a clock recovery and data regeneration unit 107 which is used to regenerate the modulation data 14 sent from the local distribution node 3. As shown, this data is output to the user unit 39. Figure 7 also shows that the signal 97 is input directly to the microprocessor 105, via the analogue to digital converter 103, so that the microprocessor 105 can (i) continuously monitor the signal strength of the received beam; (ii) store, in the memory 109, the recent history of the received signal strength; and (iii) if appropriate, output a control signal to the laser control unit 41 in order to reduce the power of the transmitted laser beam.

In the above embodiment, two mirrors were mounted for rotation about orthogonal axes so that the user terminals can steer their laser beams towards the retro-reflector within the local distribution node. As those skilled in the art will appreciate, other arrangements are possible. For example, a single mirror may be used if two-axis movement is provided. Further, rather than using reflective mirrors, a similar steering operation can be achieved using refraction or diffraction techniques. An example of a diffractive technique would

be to use an acousto-optic scanner in which a surface acoustic wave is launched into a piezoelectric material, the propagation wave forming a moving diffraction grating. A laser beam incident on the piezoelectric material is then diffracted by the grating, with the angle of diffraction being related to the grating pitch, and hence to the drive frequency. The laser beam is therefore steered by variation of the drive frequency. However, this type of system is not preferred due to high cost, low efficiency and the need to provide relatively high drive frequencies (several MHz).

A second type of diffractive system is the hologon, named by analogy with the polygon reflective scanner found in laser printers. Such a system comprises a disk of transparent material (typically glass or plastic) whose surface is embossed with a computer generated hologram. The hologram is designed to deflect an incoming laser beam through an angle which depends on the position of the beam on the surface of disk. Steering of the beam is achieved by rotating the disk with respect to the incident beam. Typically, two such hologons would be required to steer the beam in two directions. Such a diffractive system has the advantages that the hologons may be mounted on stepper motors and hence only consume power during a change in beam steering; the beam deflection achieved is set in advance by design and can be chosen arbitrarily; and the hologons are cheap since they can be embossed like a CD. However, the hologon

system suffers from the disadvantage of high design and tooling costs for the hologon and low optical efficiency since some of the optical power is lost through the diffraction process.

Refractive steering of the laser beam may be achieved using two wedge prisms. Such a system is shown in Figure 8. In particular, Figure 8 shows the main components of a user terminal which employs two wedge shape prisms 109-1 and 109-2 located between the optical beam expander 27 and the beamsplitter 25. If the two prisms 109 are rotated by an equal amount but in opposite directions, the laser beam is steered in the horizontal plane. The amount of the deviation is set by the angle of rotation, the prism wedge angle and the prism refractive index. To achieve vertical deviation of the laser beam, the two prisms are rotated in the same direction, to effectively rotate the plane of deviation. Therefore, any arbitrary θ, ϕ deviation can be achieved.

The refractive solution illustrated in Figure 8 has a number of advantages. In particular, the prism parameters can be chosen so that a full rotation of the prisms gives the full range of deviation required, thereby minimising the precision required of the rotation mechanism (not shown) used to rotate the prisms. Additionally, the prisms can be readily rotated using stepper motors which only require power during a change in the beam steering. Further, since a similar optical

system has been used since approximately 1930, to implement range finders in a number of cameras, the prisms and rotation mechanisms required are readily available and low cost items.

In the first embodiment described above, a high powered laser was used and the power output of the laser was reduced in the event of the beam being interrupted. As those skilled in the art will appreciate, the ability to be able to control the power of the laser beam in this way is applicable to any retro-reflecting communication technique, since the received signal level gives a reliable indication of the link integrity and since the laser is physically located at the receiver end, its output power can be controlled by electronics at the receiver.

In the above embodiments, an array of QCSE modulators were used in the retro-reflecting end of the communications link. These QCSE modulators either absorb or reflect incident light. As those skilled in the art will appreciate, other types of reflectors and modulators can be used. For example, a plane mirror may be used as the reflector and a transmissive modulator (such as a liquid crystal) may be provided between the lens and the mirror. Alternatively still, beamsplitters may be used to temporarily separate the path of the incoming beam from the path of the reflected beam and, in this case, the modulator may be provided in the path of the

reflected beam so that only the reflected light is modulated. However, such an embodiment is not preferred since it requires additional optical components to split the forward and return paths and then to recombine the paths after modulation has been effected.

In the above embodiment, a telecentric lens was used In front of the array of retro-reflectors. Whilst the use of a telecentric lens is preferred, it is not essential. Further, if a telecentric lens is used, the back focal plane of the lens may be curved or partially curved, in which case the array of modulators should also be curved or partially curved to match the back focal plane of the telecentric lens.

In the above embodiments, a multipoint to point signalling system has been described. As those skilled in the art will appreciate, many of the advantages of the systems described above will also apply to point to point signalling systems, to point to multipoint signalling systems and to multipoint to multipoint signalling systems.

In the above embodiment, the amplitude modulation of the signal strength caused by the oscillation of the mirrors was detected by mixing the signal with the dither signals. As those skilled in the art will appreciate, other techniques may be used. For example, the microprocessor 105 may detect the variation in the signal

strength from the digital samples generated from the received signal itself. The microprocessor 105 could then cause the beam to be steered in a direction and if the variation increases then it can steer the laser beam in the opposite direction.

CLAIMS

1. An optical signalling system comprising first and second signalling devices,

the first signalling device comprising means for receiving an optical signal transmitted from said second signalling device; and means for modulating the received optical signal with modulation data for the second signalling device and for reflecting the received signal back to the second signalling device; and

the second signalling device comprising: means for generating an optical signal; means for outputting the optical signal toward said first signalling device; means for receiving the reflected optical signal from said first signalling device carrying said modulation data; and means for retrieving the modulation data from said reflected signal;

characterised in that said second signalling device further comprises:

means for controllably steering the optical signal generated by said generating means towards said first signalling device;

means for sensing the signal strength of the reflected signal; and

means for controlling said steering means in

dependence upon the sensed signal strength.

2. A system according to claim 1, wherein said steering means comprising means for reflecting said optical signal.

3. A system according to claim 2, wherein said steering means comprises one or mirrors pivotally mounted relative to said generated optical signal.

4. A system according to claim 1, wherein said steering means comprises means for diffracting said generated optical signal.

5. A system according to claim 4, wherein said diffraction means comprises a moving diffraction grating.

6. A system according to claim 4, wherein said diffraction means comprises a hologram.

7. A system according to claim 6, wherein said hologram is movable relative to the generated optical signal.

8. A system according to claim 1, wherein said steering means comprises means for refracting the generated

optical signal.

9. A system according to claim 8, wherein said refracting means comprises first and second prisms.

10. A system according to claim 9, wherein said steering means is operable to steer said generated optical signal by rotating said prisms relative to said generated optical signal.

11. A system according to claim 10, wherein said first and second prisms are rotatable about the axis of the generated optical signal and wherein said steering means is operable to rotate the two prisms in opposite directions to steer the generated optical signal in a first direction and is operable to rotate the first and second prisms in the same direction to steer the generated optical signal in a second different direction.

12. A system according to any of claims 9 to 11, wherein said first and second prisms are wedge shaped.

13. A system according to any preceding claim, wherein said sensing means is operable to monitor the signal st0ength of said reflected optical signal and wherein

said control means is operable to control said steering means in dependence upon the monitored signal levels.

14. A system according to any preceding claim, wherein said control means is operable to oscillate said steering means, wherein said sensing means is operable to sense a variation in the signal strength caused by said oscillation and wherein said control means is operable to control said steering means in dependence upon the sensed variation.

15. A system according to claim 14, wherein said sensing means comprises a phase sensitive amplitude modulation detecting means.

16. A system according to claim 15, wherein said control means is operable to oscillate said steering means in accordance with at least one dither signal and wherein said detecting means comprises means for mixing said reflected signal with the at least one dither signal.

17. A system according to any preceding claim, wherein said control means comprises a microprocessor.

18. A system according to any preceding claim, wherein

said generating means is operable to generate an optical signal at a first power level and wherein said second signalling device further comprises power control means for reducing the power output of said generating means to a second power level in dependence upon the signal level of said reflected signal sensed by said sensing means.

19. A system according to claim 18, wherein said sensing means is operable to monitor a recent history of the received signal level and wherein said power control means is operable to reduce the power output of said generating means in dependence upon said recent history.

20. A system according to claim 19, wherein said sensing means is operable to sense the level of the reflected signal at regular intervals and wherein said power control means is operable to reduce the power output of said generating means if the change in signal level between sensing intervals exceeds a predetermined threshold.

21. A system according to any preceding claim, wherein said control means comprises one on more stepper motors for controlling said steering means.

22. A system according to any preceding claim, wherein said first signalling device further comprises focussing means for focussing the received optical signal onto said reflecting means.

23. A system according to claim 22, wherein said focussing means comprises a telecentric lens and wherein said reflecting means is located substantially at the focal plane of said lens.

24. A system according to claim 23, wherein said telecentric lens is a wide angled telecentric lens.

25. A system according to any of claims 22 to 24, wherein said modulating means is transmissive and is located between said focussing means and said reflecting means.

26. A system according to any preceding claim, wherein said modulating means and said reflecting means are collocated.

27. A system according to any of claims 1 to 25, wherein said modulating means and said reflecting means are separate elements.

28. A system according to any preceding claim, wherein said first signalling device comprises a plurality of modulating and reflecting means for modulating and reflecting optical signals received from a plurality of second signalling devices.

29. A system according to claim 28, wherein said plurality of modulating and reflecting means are arranged in an array.

30. A system according to claim 29, wherein said plurality of modulating and reflecting means are arranged in a regular array.

31. A system according to claim 30, wherein said plurality of modulating and reflecting means are arranged in a two dimensional array.

32. A system according to any preceding claim, wherein said reflecting means comprises a retro-reflector.

33. A system according to any preceding claim, wherein said modulating means is operable to modulate at least one of the amplitude, phase, frequency or polarisation of the received signal.

34. A system according to any preceding claim, wherein said modulating means comprises a quantum confined stark effect device.

35. A system according to any preceding claim, wherein said second signalling device is operable to transmit a message to said first signalling device and wherein said first signalling device comprises means for retrieving the message from the received signal.

36. A system according to any preceding claim, wherein said generating means comprises a laser, a laser diode or a light emitting diode.

37. A system according to any preceding claim, wherein said second signalling device further comprises an optical beam expander for increasing the diameter of the optical signal output towards said first signalling device.

38. A second signalling device comprising: means for generating an optical signal; means for outputting the optical signal towards a first signalling device; means for receiving a reflected optical signal from said first signalling device carrying modulation data; and means for

retrieving the modulation data from said reflected signal;

characterised in that said second signalling device further comprises:

means for controllably steering the optical signal generated by said generating means towards said first signalling device;

means for sensing the signal strength of the reflected signal; and

means for controlling said steering means in dependence upon the sensed signal strength.

39. A second signalling device comprising the technical second signalling device features of any of claims 1 to 37.

40. A signalling kit comprising one or more first signalling devices and one or more second signalling devices according to claim 38 or 39.

41. An optical signalling method using first and second signalling devices, the method comprising the steps of:

at the first signalling device: receiving an optical signal transmitted from said second signalling device; modulating the received optical signal with modulation

data for the second signalling device; and reflecting the received signal back to the second signalling device; and

at the second signalling device: generating an optical signal; outputting the optical signal towards said first signalling device; receiving the reflected optical signal from said first signalling device carrying said modulation data; and retrieving the modulation data from said reflected signal;

characterised by the following steps performed at the second signalling device:

controllably steering the optical signal generated in said generating step towards said first signalling device;

sensing the signal strength of the reflected signal; and

controlling said steering step in dependence upon the sensed signal strength.

42. A retro-reflecting optical communications system comprising an optical source end and a reflecting end, characterised in that the source end comprises:

means for controllably steering a generated optical signal towards said first signalling device;

means for sensing the signal strength of a reflected signal received back from said reflecting end; and

means for controlling said steering means in dependence upon the sensed signal strength.

43. An optical signalling system comprising first and second signalling devices,

the first signalling device comprising means for receiving an optical signal transmitted from said second signalling device; and means for modulating the received optical signal with modulation data for the second signalling device and for reflecting the received signal back to the second signalling device; and

the second signalling device comprising: means for generating an optical signal at a first power level; means for outputting the optical signal towards said first signalling device; means for receiving the reflected optical signal from said first signalling device carrying said modulation data; and means for retrieving the modulation data from said reflected signal;

characterised in that said second signalling device further comprises:

means for sensing the signal strength of the reflected signal; and

power control means for reducing the power output of said generating means to a second lower power level in

dependence upon the sensed signal strength.

44. A system according to claim 43, wherein said sensing means is operable to monitor a recent history of the received signal level and wherein said power control means is operable to reduce the power output of said generating means in dependence upon said recent history.

45. A system according to claim 44, wherein said sensing means is operable to sense the level of the reflected signal at regular intervals and wherein said power control means is operable to reduce the power output of said generating means if the change in signal level between sensing intervals exceeds a predetermined threshold.

46. A data distribution system comprising one or more signalling systems according to any of claims 1 to 37 or 43 to 45.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
18 January 2001 (18.01.2001)

PCT

(10) International Publication Number
WO 01/05072 A1

(51) International Patent Classification[7]: H04B 10/26, 10/10, 10/207

(21) International Application Number: PCT/GB00/02633

(22) International Filing Date: 10 July 2000 (10.07.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

9916081.4	8 July 1999 (08.07.1999)	GB
9916082.2	8 July 1999 (08.07.1999)	GB

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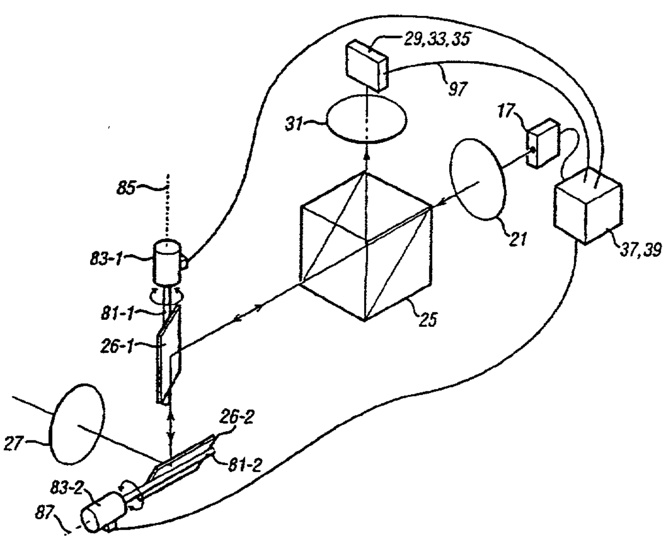
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: SIGNALLING SYSTEM



(57) **Abstract:** An optical signalling system is provided comprising first and second signalling devices. The first signalling device comprises a retro-reflector and the second signalling device comprises a light source for transmitting light towards the retro-reflector. The second signalling device also includes means for controllably steering the optical signal towards the first signalling device, means for sensing the signal strength of the reflected signal; and means for controlling the steering means in dependence upon the sensed signal strength. The steering means may steer the beam using reflective, refractive or diffractive techniques.

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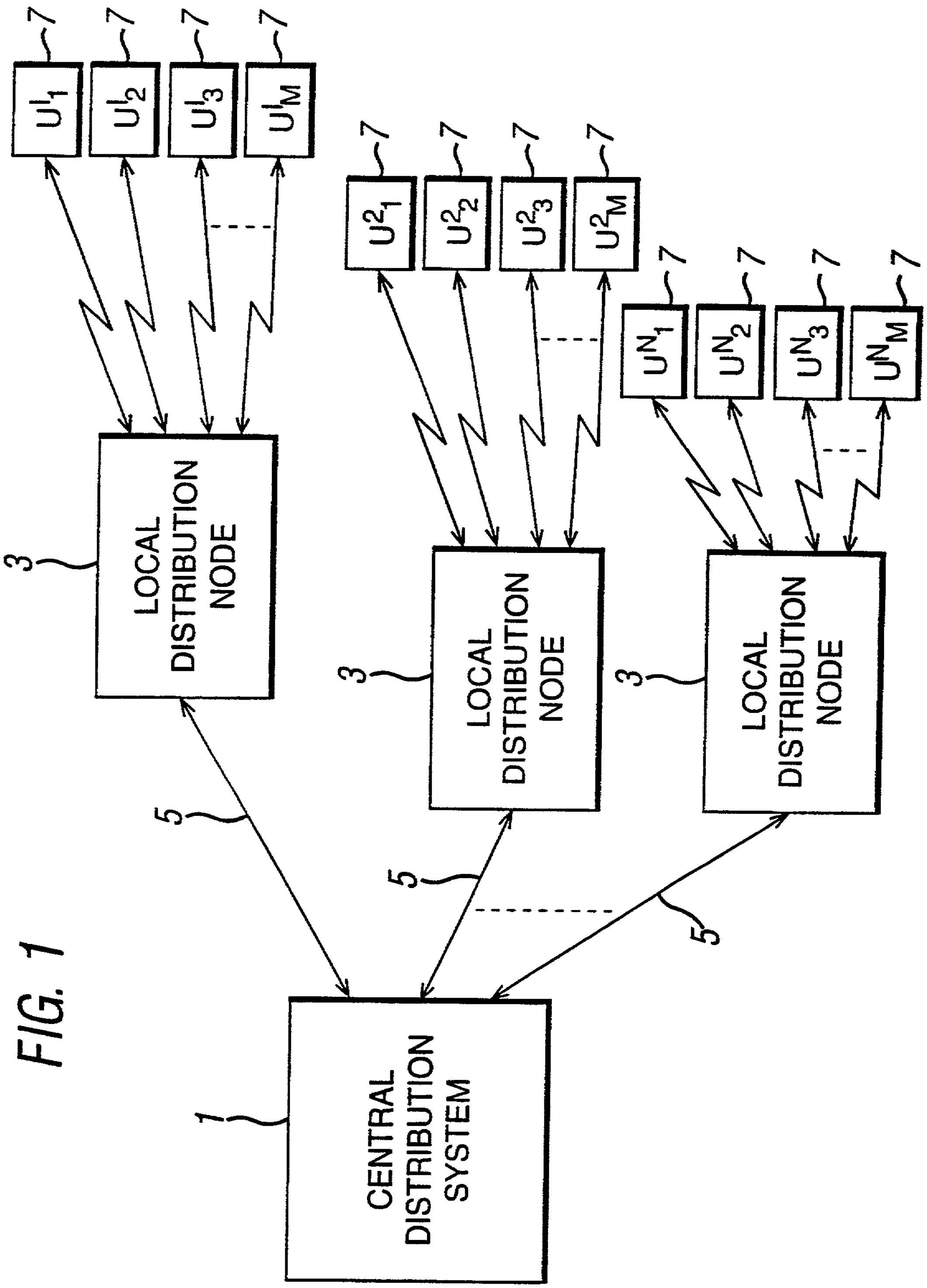

CENTRAL DISTRIBUTION SYSTEM
LOCAL DISTRIBUTION NODE
LOCAL DISTRIBUTION NODE
LOCAL DISTRIBUTION NODE
1
3
5
7

FIG. 1

10/030357

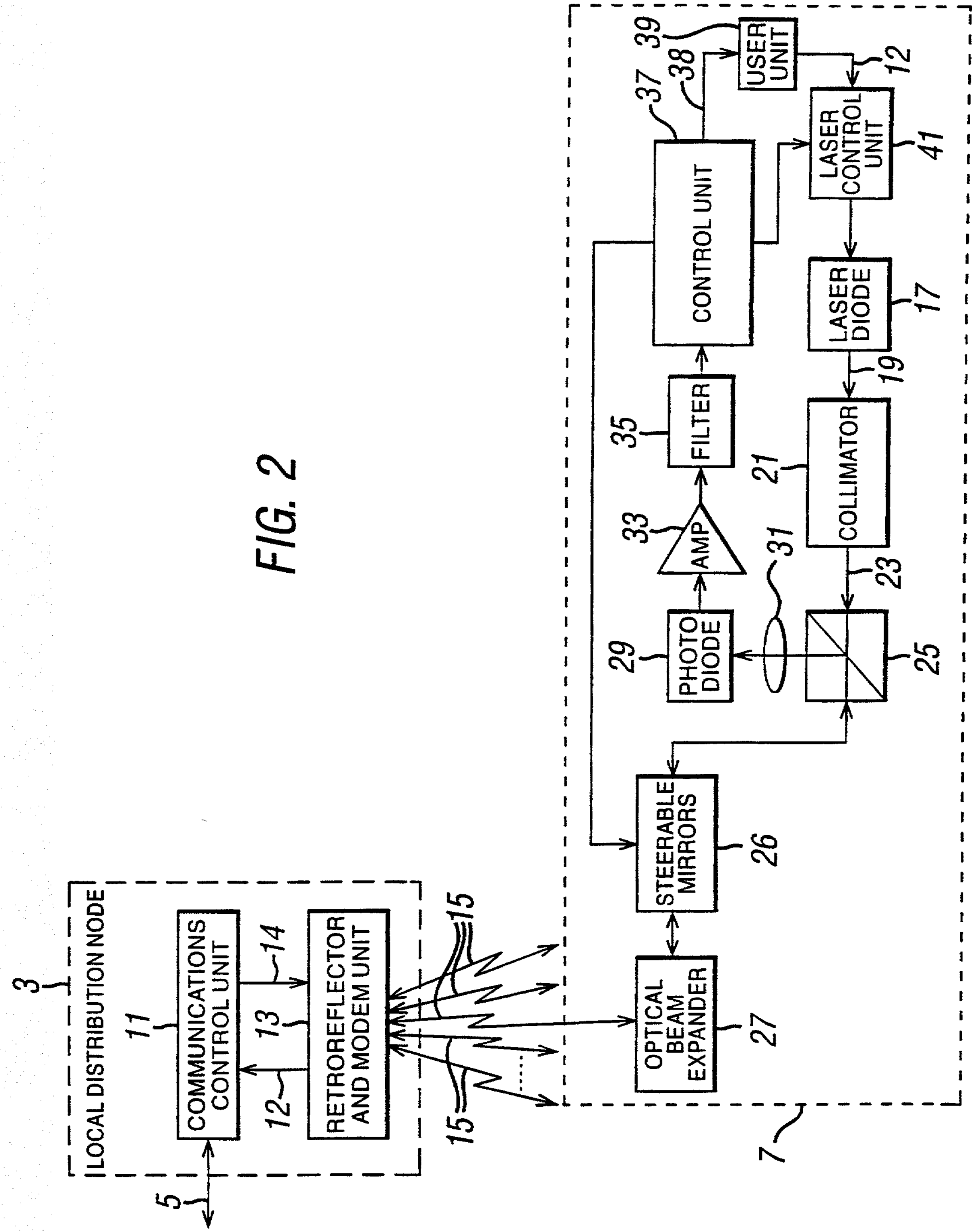


FIG. 2

FIG. 3

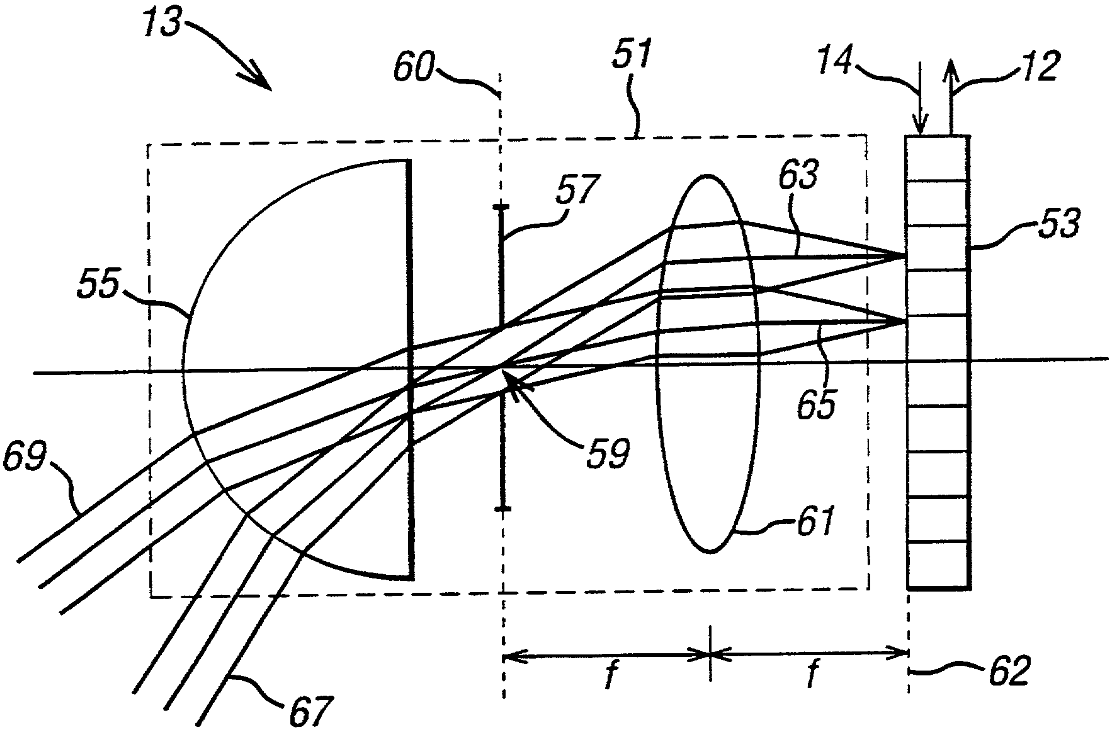
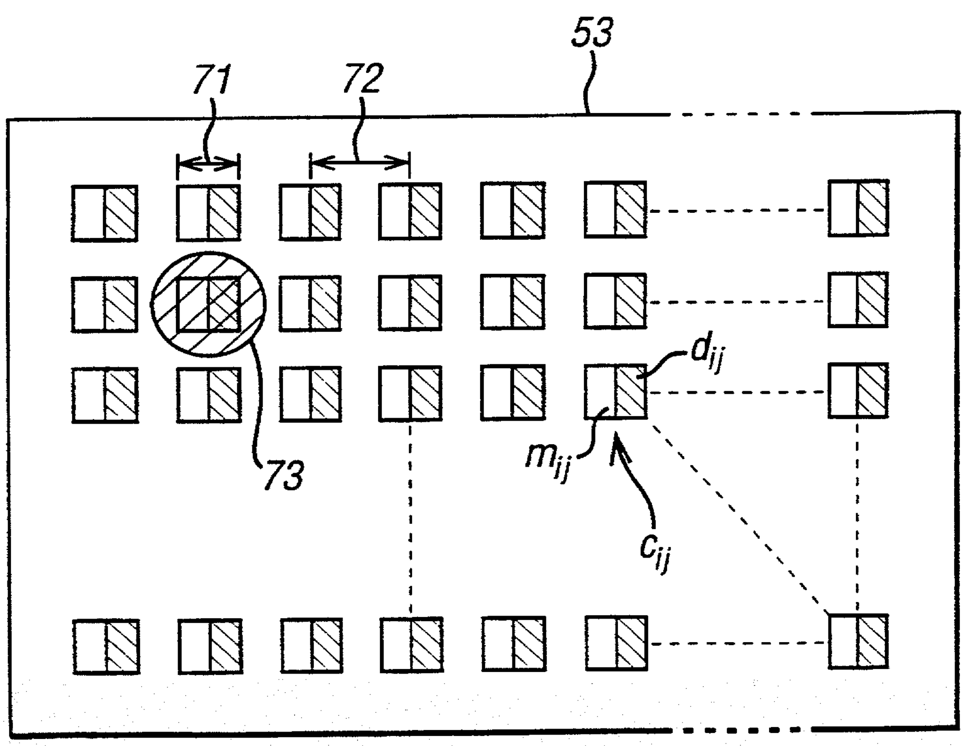


FIG. 4



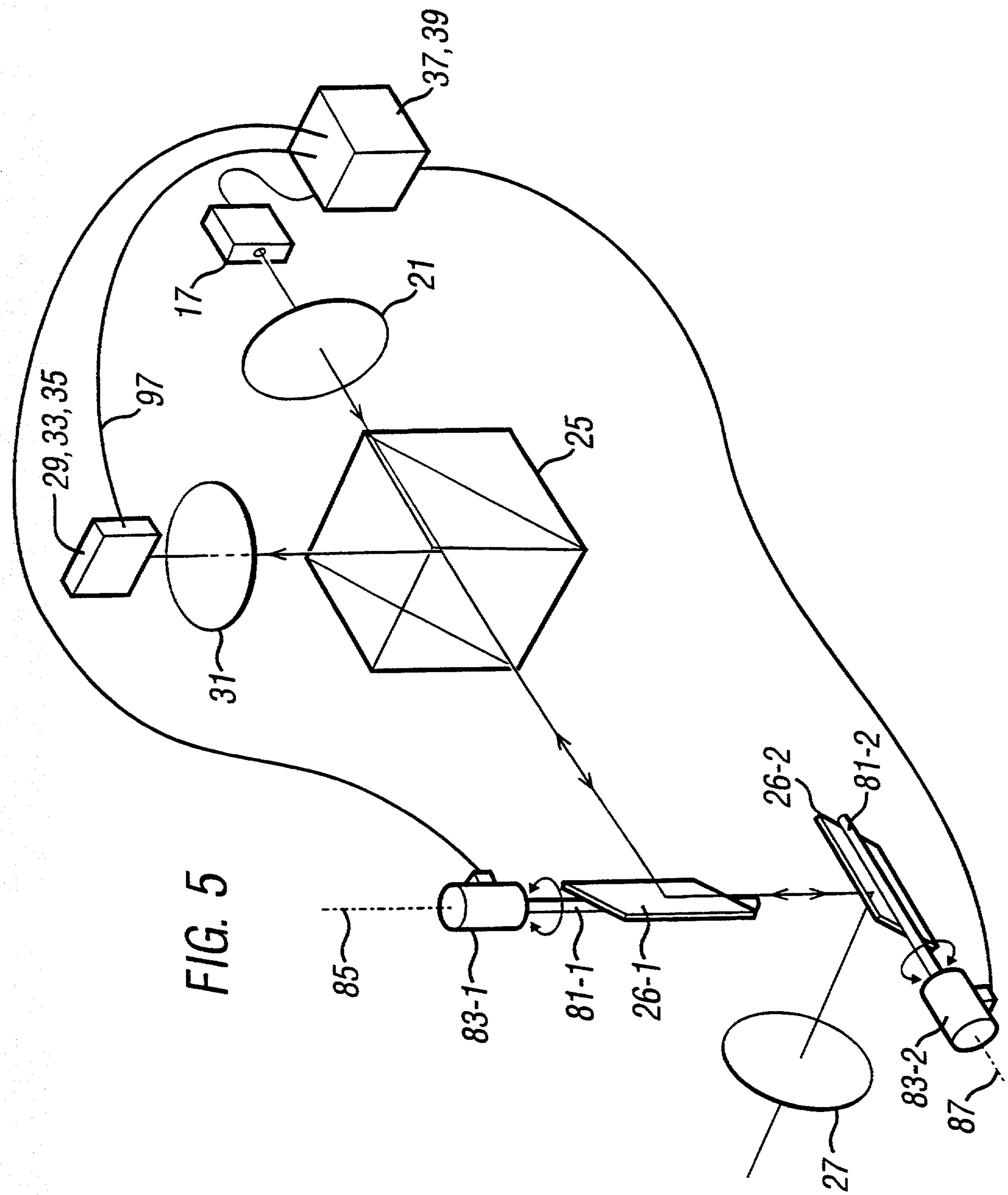


FIG. 5

FIG. 6

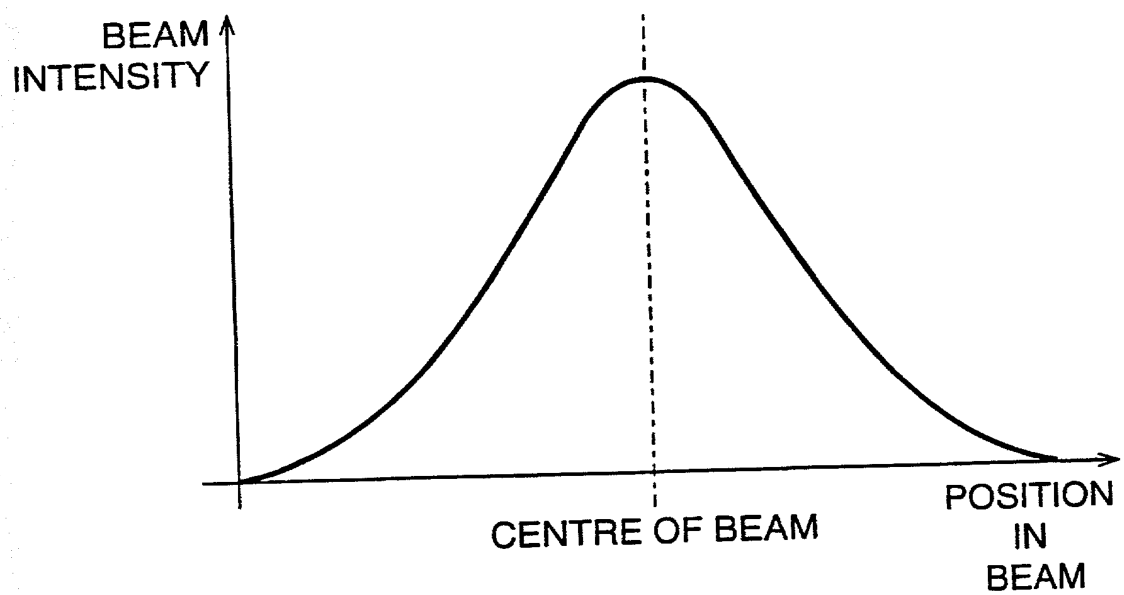
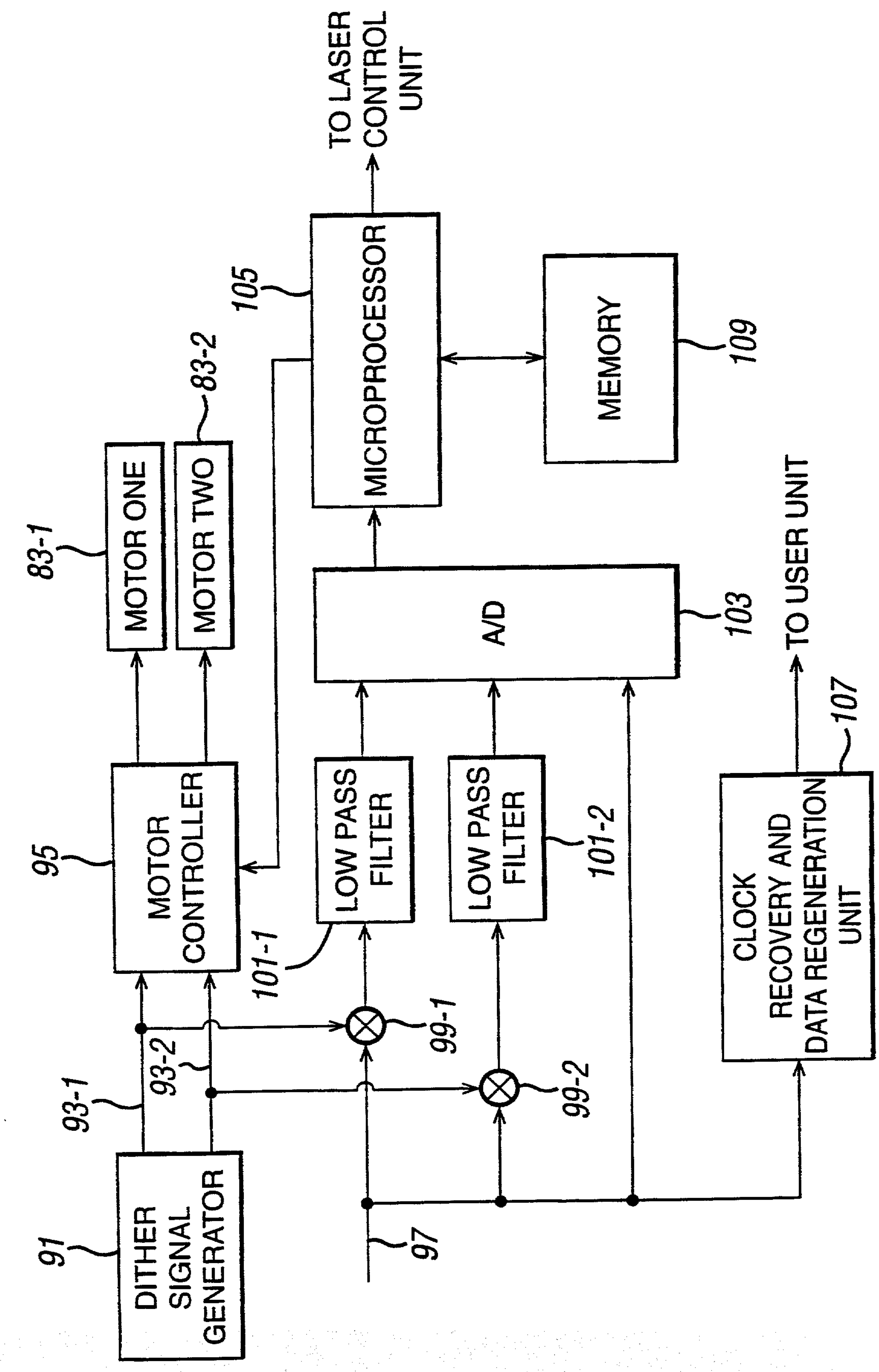


FIG. 7


DITHER SIGNAL GENERATOR
91
93-1
93-2
MOTOR CONTROLLER
95
MOTOR ONE
83-1
MOTOR TWO
83-2
97
99-1
99-2
LOW PASS FILTER
101-1
LOW PASS FILTER
101-2
A/D
103
MICROPROCESSOR
105
TO LASER CONTROL UNIT
MEMORY
109
CLOCK RECOVERY AND DATA REGENERATION UNIT
107
TO USER UNIT

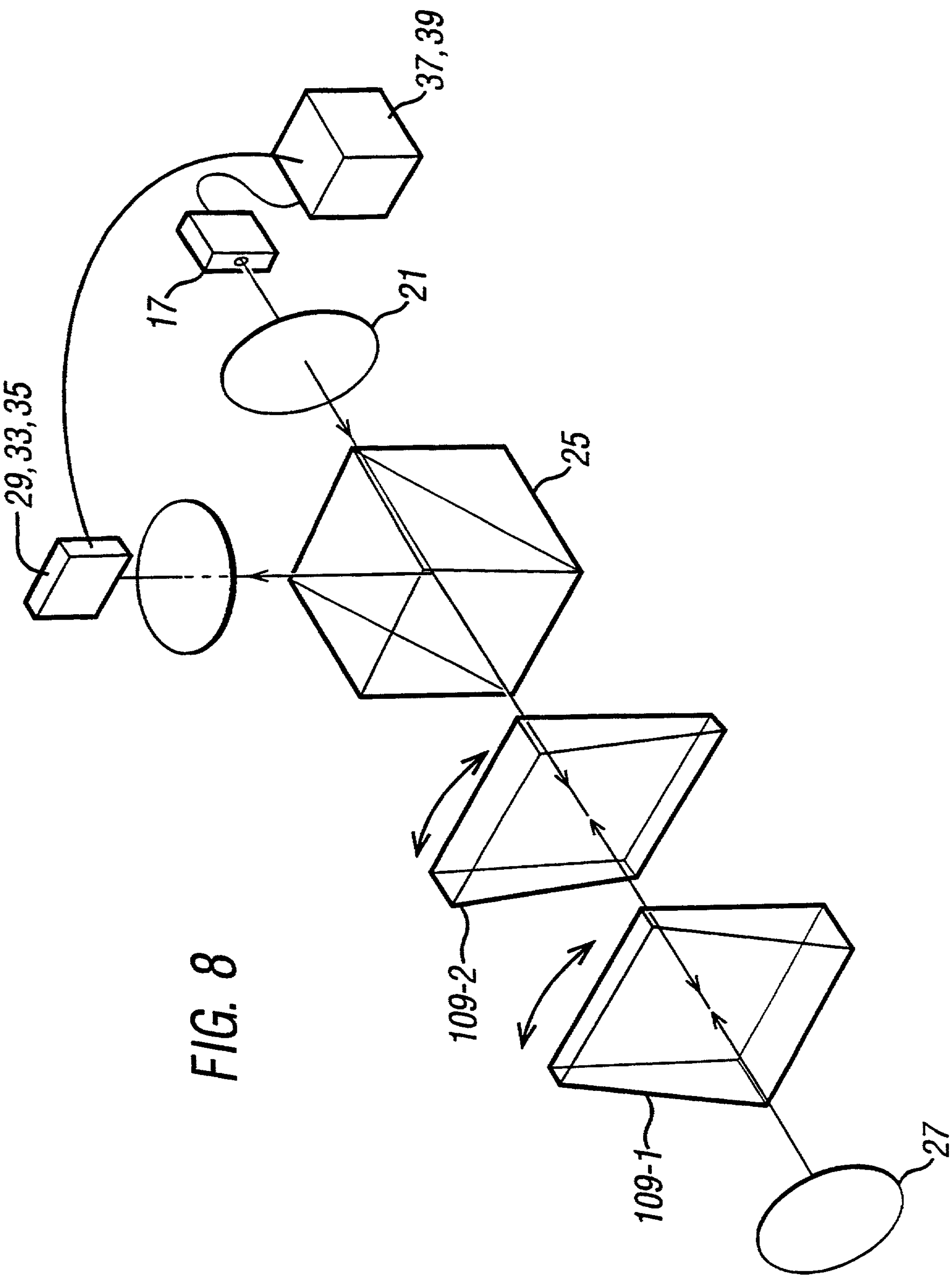


FIG. 8

DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that: my residence, post office address and citizenship are as stated below next to my name; I believe I am the original, first, and sole inventor (if only one name is listed below) or an original, first, and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

SIGNALLING SYSTEM

the specification of which
☐ is attached and/or
☒ was filed on January 8, 2002 as United States Application Serial No. 10/030,357 and was amended on January 8, 2002. or
☒ PCT International Application No. PCT/GB/00/02633, filed July 10, 2000.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above. I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR § 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. § 119(a)-(d) or § 365(b) of any foreign application(s) for patent or inventor's certificate or § 365(a) of any PCT international application(s) designating at least one country other than the United States, listed below and have also identified below, any foreign application(s) for patent or inventor's certificate, or any PCT International application(s) having a filing date before that of the application(s) of which priority is claimed:

Country	Application Number	Date of Filing	Priority Claimed Under 35 U.S.C. 119
Great Britain	9916081.4	July 8, 1999	☒ YES ☐ NO
Great Britain	9916082.2	July 8, 1999	☒ YES ☐ NO

I hereby claim the benefit under 35 U.S.C. § 119(e) of any United States provisional application(s) listed below:

Application Number	Date of Filing

I hereby claim the benefit under 35 U.S.C. § 120 of any United States application(s) or § 365(c) of any PCT International application(s) designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application(s) in the manner provided by the first paragraph of 35 U.S.C. § 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR § 1.56 which became available between the filing date of the prior application(s) and the national or PCT International filing date of this application:

Application Number	Date of Filing	Status (Patented, Pending, Abandoned)

I hereby appoint the following attorney and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. **FINNEGAN, HENDERSON, FARABOW, GARRETT & DUNNER, L.L.P., CUSTOMER NUMBER 22,852**, Douglas B. Henderson, Reg. No. 20,291; Ford F. Farabow, Jr., Reg. No. 20,630; Arthur S. Garrett, Reg. No. 20,338; Donald R. Dunner, Reg. No. 19,073; Brian G. Brunsvold, Reg. No. 22,593; Tipton D. Jennings, IV, Reg. No. 20,645; Jerry D. Voight, Reg. No. 23,020; Laurence R. Hefter, Reg. No. 20,827; Kenneth E. Payne, Reg. No. 23,098; Herbert H. Mintz, Reg. No. 26,691; C. Larry O'Rourke, Reg. No. 26,014; Albert J. Santorelli, Reg. No. 22,610; Michael C. Elmer, Reg. No. 25,857; Richard H. Smith, Reg. No. 20,609; Stephen L. Peterson, Reg. No. 26,325; John M. Romary, Reg. No. 26,331; Bruce C. Zotter, Reg. No. 27,680; Dennis P. O'Reilley, Reg. No. 27,932; Allen M. Sokal, Reg. No. 26,695; Robert D. Bajefsky, Reg. No. 25,387; Richard L. Stroup, Reg. No. 28,478; David W. Hill, Reg. No. 28,220; Thomas L. Irving, Reg. No. 28,619; Charles E. Lipsey, Reg. No. 28,165; Thomas W. Winland, Reg. No. 27,605; Basil J. Lewris, Reg. No. 28,818; Martin I. Fuchs, Reg. No. 28,508; E. Robert Yoches, Reg. No. 30,120; Barry W. Graham, Reg. No. 29,924; Susan Haberman Griffen, Reg. No. 30,907; Richard B. Racine, Reg. No. 30,415; Thomas H. Jenkins, Reg. No. 30,857; Robert E. Converse, Jr., Reg. No. 27,432; Clair X. Mullen, Jr., Reg. No. 20,348; Christopher P. Foley, Reg. No. 31,354; John C. Paul, Reg. No. 30,413; Roger D. Taylor,

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

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Listing of Inventors Continued on Page 2 hereof. ☐ Yes ☐ No